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6800-year vegetation and fire history in the Bitterroot Mountain Range Montana

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A 6800-YEAR VEGETATION AND FIRE HISTORY IN THE BITTERROOT MOUNTAIN RANGE, MONTANA

By

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A 6800-Year Vegetation and Fire History in the Bitterroot Mountain Range, Montana.

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The vegetation community near Marys Pond, Montana was analyzed through fossil pollen and microscopic charcoal in 46 samples from two combined sediment cores. Soon after the fall of Mazama ash (6850 B.P.; Bacon 1983) the vegetation community was briefly dominated by nonarboreal species. From about 6200-3500 yr B.P. vegetation of the surrounding area is represented by a Pinus (probably Pinus contorta) Pseudotsuga/Larix community suggesting a warmer climate with less effective moisture. While Pinus remains dominant, there was a suggested shift to mixed coniferous forest after 3500-2000 yr B.P. decreasing in the Pseudotsuga/Larix and increasing in Abies and Picea. This change in plant community may have indicated a cooling of temperatures and more moisture availability. By 2000 yr B.P., the forest appeared similar to the vegetation community presently surrounding Marys Pond characterized by a dominance of Pinus mixed with Abies, Larix and Picea. A similar shift in plant composition in response to temperature and moisture changes was observed at three other sites in western Montana where pollen analysis studies have been completed.

Except for two samples, the microscopic charcoal analysis suggests a continuous series of variable intensity fires throughout the last 6800 years. Two distinct periods of high fire frequency and/or intensity centered around 3300 yr B.P. and 4000 yr B.P. are evident in the charcoal and pollen record. These may represent episodes of double or triple burn events.

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INTRODUCTION

A common ecological misconception is to regard landscapes as balanced, steady state communities defined by specific structures, functional processes and species composition (Tausch *et al.*, 1993). This vision is perpetuated in popular culture with images of majestic "old growth" forests in movies, literature, and the evening news. One potential origin of this thought in the research community can be found in Clements' theory of climax vegetation. He viewed plant associations as discrete complexes which arise, grow, mature, and die through predictable biological steps of organization (Clements, 1916). The antithesis of this theory is well grounded in Gleason's hypothesis on the individualistic response of plant communities (Gleason, 1926). Each plant adjusts independently to biotic and abiotic changes in their environment.

The paleoevironmental record adds further credence to Gleason's hypothesis by tracing plant communities as transient assemblages of varying species composition through time (Davis, 1981; Mehringer, 1985; Brubaker, 1988; Schoonmaker and Foster, 1991). Pollen studies have illustrated that each plant species has a different history since the retreat of Pleistocene glaciers (Davis, 1969). As an example, several researchers have determined that Tsuga heterophylla (western hemlock), a species well established in the area today, first appeared in northern Idaho less than 3000 years ago (Mack *et al.*, 1978; Mehringer, personal communication). Current ecological research tends to favor the individualist response of communities. Yet, there is an apparent lag time between the rise of a new scientific theory, and its general recognition.

Pollen analysis provides a long-term description of vegetation history. By knowing which plants were present, the ecological framework of the constituents in the plant communities and their relative abundance, inferences can be made concerning the climate and vegetation dynamics present at the time the pollen was deposited (Faegri and Iversen, 1989). Further conclusions regarding causal relationships are tenuous. The power of pollen analysis originates in its ability to identify the dominant vegetation on the landscape; this knowledge suggests general climatic factors affecting vegetation based on modern pollen assemblages (Davis, 1969).

In the current context of broad scale landscape analysis, knowledge of past vegetation associations and ecological processes shed light on the variety of pathways affecting the current landscape mosaics (Hann, 1989). As ecologists and land managers strive to understand present-day forest structural patterns, it has become increasingly evident how fractured the picture is without an understanding of the past.

> "One striking result of the study is a realization that little evidence of the prior vegetation, including the original forest, or past land-use is apparent in the modern landscape... This great deceptiveness in the appearance of the forest to the modern investigator highlights the utility of diverse approaches to understanding and characterizing forest communities." (Foster *et al.*, 1992).

An elucidation of vegetation change through time can be used to view the processes that may have contributed to the present mosaic of plant communities across the landscape. Investigations using pollen analysis range from constructing the vegetation history of an entire region to reconstructing the biological history of a particular plant species (Faegri and Iversen, 1989). In the northern Rocky Mountains, the focus of pollen studies has been primarily on the reconstruction of vegetation communities and climate change, (Waddington and Wright, 1974; Davis *et al.*, 1977; Mack *et al.*, 1978, 1983; Barnosky, 1989; Barnosky *et al.*, 1987) , and the characterization of fire regimes (Mehringer *et al.*, 1977a; Smith, 1983; Hemphill, 1983; Onken, 1984).

I have characterized 6800 years of vegetation change and fire history at Marys Pond in the Bitterroot Mountain Range of western Montana. Plant associations are deduced from sequential pollen deposition and fire frequency determined by charcoal analysis. This study contributes to the sparse, but growing number of places in the interior Pacific Northwest where detailed pollen studies have been completed (for a review see Mehringer, 1985). The resulting paleoecological description illustrates how past vegetation communities and ecological processes have evolved. As the long term history of each new site is interpreted, more precise inferences can be made of the ecological amplitudes which shaped regional landscapes of the past.

OBJECTIVES

The following objectives were established for analysis of sediment samples from Marys Pond:

(1). describe the changing vegetation assemblages through the use of microfossils;

(2). reconstruct fire history of the area through charcoal influx;

(3). compare the resulting vegetation and fire history with other studies in the region.

LITERATURE REVIEW

Pollen and Fire History Studies

The first efforts towards reconstructing past vegetation communities in this region were forged by palynologist Henry P. Hansen in the 1940's. His studies took him from Oregon up through Washington, across northern Idaho, and into western Montana. Specific sites Hansen studied in the region surrounding Marys Pond include Bonners Ferry (Hansen, 1943) and Hagar Pond (Hansen, 1939) in north Idaho plus Fish Lake and Johns Lake in Glacier National Park (Hansen, 1948).

Pollen and charcoal analysis of three sites have been conducted in the same general geographical area as Marys Pond. They include Sheep Mountain Bog in the Rattlesnake Mountains (Hemphill, 1983; Johnson *et al.*, 1994), Lost Trail Pass Bog in the Bitterroot Mountains (Mehringer *et al.*, 1977a) and Smeads Bench Bog in the Cabinet Mountains (Chatters and Leavell, 1994). At each locality both the fossil pollen and charcoal have been analyzed to extrapolate the vegetation change and fire history of the surrounding area. Each site contributes to the overall paleoenvironmental history of the region.

Sheep Mountain Bog developed in a small cirque at an elevation of 1920 meters. The analysis examined fire frequency by looking at microscopic charcoal, the ratio of charcoal to pollen and tree fire scars from the immediate area. Hemphill (1983) found that between 7000 and 2000 yr B.P., the fire frequency gradually decreased. After 2000 yr, B.P., the number of fires increased, however since 1100 yr B.P., the superabundance of charcoal is unprecedented in the last 12,000 years. This dramatic increase is attributed to human land use influences rather than climatic change.

An analysis of 167 charcoal layers in graded sediment beds at Sheep Mountain Bog afforded a 6000-year record of the number and intensity of fires between ~10,200 and ~4000 yr B.P. (Johnson *et al.*, 1994). Many small fires with occasional large fires were evident around 8000 yr B.P. By 6000 yr B.P., the fire regime was characterized by frequent small fires. Between 5400 and 4200 yr B.P. numerous small fires continue with the addition of three potentially stand replacing fires. These three fire events were unlike the fire regime of the earlier period or the last 1000 years (Johnson *et al.*, 1994).

The analysis at Lost Trail Pass Bog, at an elevation of 2152 meters, shows that a sagebrush steppe community dominated the landscape just after the retreat of glacial ice 12,000 years ago (Mehringer *et al.*, 1977a). Pines [thought to be Pinus albicaulis (whitebark pine)] soon replace the steppe suggesting cooler climatic conditions for the 3000 to 4000 years of their dominance. Pseudotsuga menziesii (Douglas-fir) and different pines [this time thought to be Pinus contorta (lodgepole pine)] replace whitebark pine, and charcoal is more abundant. By 4000 yr B.P., Douglas-fir had declined and pines dominated. As with Sheep Mountain Bog, the fire frequency shows a dramatic increase during the last 2000 yr B.P. This is again attributed to human influence on the landscape.

Smeads Bench Bog provides an analysis of a plant community at a lower elevation (1190 meters) in a moist forest type (Chatters and Leavell, 1994). The study focuses on the last 1500-years of vegetation change and fire history. This corresponds with the time that Tsuga heterophylla (western hemlock) forests have surrounded the bog. Seven stand replacing fires were observed, each followed by periods of forest regeneration. During the 1500 years, two fire regimes occur: one with a mean fire interval of 135 years and a second with an average fire interval of more than 283 years. The results from this study were designed as recommendations to land managers making multiple land use decision on public lands. This reflects the current trend towards conducting large scale ecological analysis of forested lands.

Use of Microscopic Charcoal for Interpreting Fire History

Fire history combined with the pollen record may provide an understanding of the interactions between disturbances and vegetation dynamics. Studies of microscopic charcoal have been directed toward interpreting the effects of fire on plant communities (Swain, 1981; Green, 1981) or the effects of human disturbances (Hemphill, 1983; Mehringer *et al.*, 1977a; Smith, 1983). These studies clearly illustrate the potential use of microscopic charcoal for identifying the general effects of fire on vegetation. Fire is a part of the ecosystem and may be some indicator of stress. The pollen record provides a context of what is happening in the plant community. Thus, the pollen and charcoal record together can provide insight into critical ecosystem interactions.

Fire history can be reconstructed through microscopic charcoal deposited in lake sediments (Patterson *et al*, 1987; Clark, 1988). However, limitations of this technique must be acknowledged to qualify the resulting data. The amount of charcoal in a sample is not only influenced by how much was originally produced, but also by dispersal and deposition rate, preservation in the sediments, sampling techniques, laboratory preparation and counting methods (Patterson *et al.*, 1987). Patterson *et al.* (1987) warn that varying placement and frequency of samples extracted from the sediment core can lead to different fire histories, and even lead to non-existent fire regimes.

Clark (1988) argues that a tight chronology of the sediments is essential for a reliable reconstruction of local fires; preferable the chronology provided from annually laminated sediments.

Despite the potential problems in reconstructing fire histories through microscopic charcoal, the technique may still provide good overviews of general trends. At Sheep Mountain Bog (Hemphill, 1983) and Lost Trail Pass Bog (Mehringer *et al.*, 1977a), an increase in charcoal during the last 2000 yr B.P. suggests an increase in fires attributed to human land use rather than climatic change. Working with varved sediments in northern United States, Swain (1978) has illustrated broad regional patterns concerning the effects of fire on vegetation communities.

In order to interpret microscopic charcoal, ratios of charcoal to total terrestrial pollen are calculated. This method tends to eliminate false peaks in the data since pollen should be redeposited along with the charcoal. Yet, immediately after a real fire, the amount of charcoal will be higher than the pollen because of the superabundance of airborne charcoal and the reduction of the pollen source (Swain, 1973). Swain (1973) considered the ratio of charcoal to pollen from Lake of the Clouds, Minnesota, the best indication of actual fires. If charcoal and pollen are transported and deposited similarly, one would expect more charcoal in relation to pollen following a fire than during times without fires. Comparing peaks of more charcoal to pollen may give an indication of individual fires (in laminated sediments) and provide the sequence of fires throughout the pollen core. Still, with redeposition, sediment mixing and delayed charcoal transportation, charcoal peaks from a single fire can span a decade or more (Patterson *et al.*, 1987).

STUDY AREA

Marys Pond is situated on a north facing slope at an elevation of 1753 meters in the Bitterroot Mountain Range, western Montana. The pond is on the Lolo National Forest, T39N, R22W Sections 15 and 22 (Figure 1). Locally it is known at Marys Frog Pond, however it appears as Marys Pond on the Dick Creek U.S.G.S. topographic map. The surface area of Marys Pond is relatively small (approximately 60 m x 200 m) and was formed by retreating ice leaving a recessional moraine in a deep, steep-sided canyon. Although the pond is approximately six meters deep, suspended sediments prevent light from penetrating over three meters (personal communication, J. Pierce, U. S. Forest Service, Regional 1).

Marys Pond is presently surrounded by an Abies lasiocarpa forest habitat type (Pfister *et al.*, 1977). A nearly pure stand of fire generated Pinus contorta with some Larix occidentalis encompasses the perimeter of the pond (see Table 1 for present-day list of plants surrounding Marys Pond). A recent history of severe fires has been compiled by Stephen F. Arno of the Intermountain Fire Science Lab in Missoula, Montana (Appendix A). Severe fires in 1805 and 1889 are dated from fire scars. The earliest fires (late 1400's and late 1600's) are extrapolated from age-class cohorts of surviving shade-intolerant Larix occidentalis that are interpreted to represent post-fire regeneration. Most of the present-day Larix occidentalis and Pinus contorta at the site became established soon after the 1889 fire.

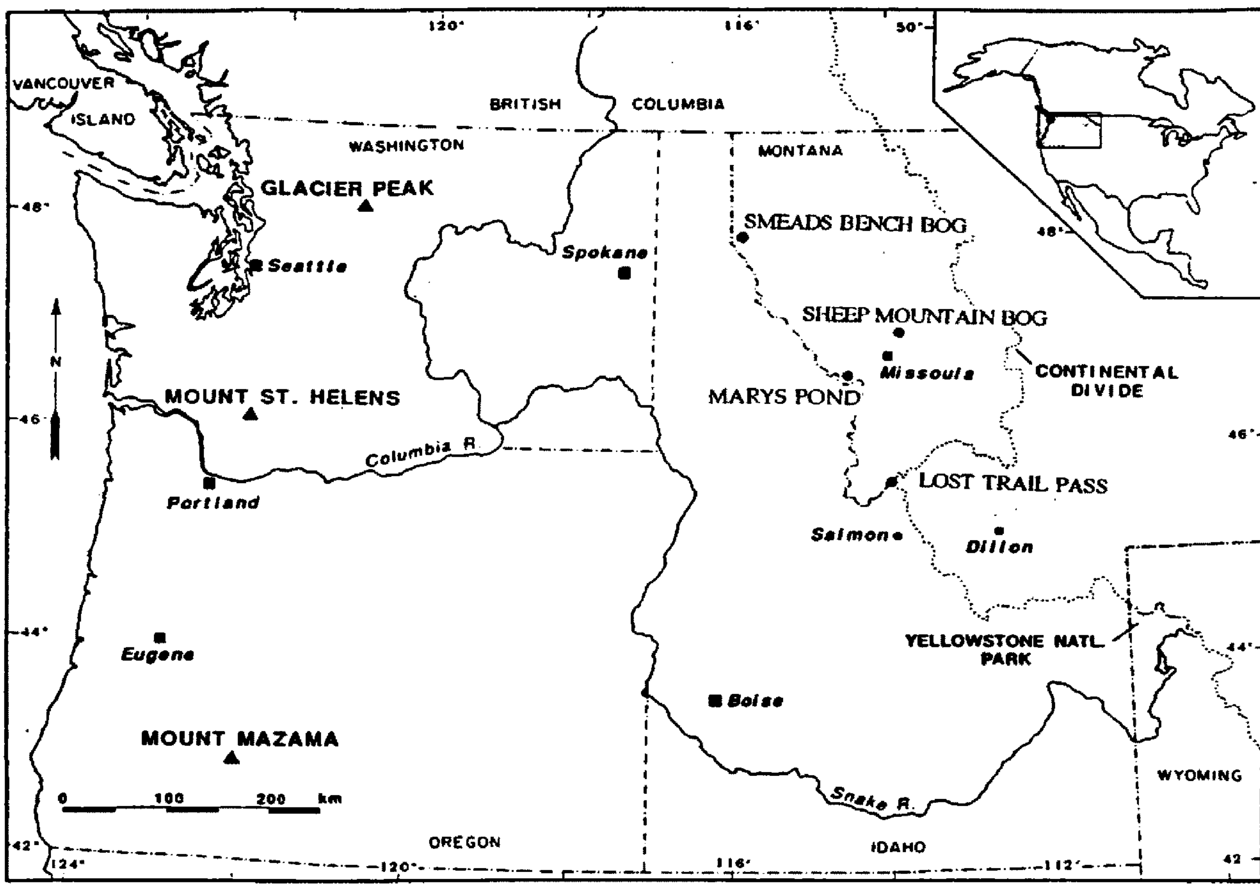

Figure 1. Map showing the location of Marys Pond and three other sites discussed in the text. ●, coring sites; ▲, Cascade volcanoes; ■, cities and towns (adapted from Foit *et al.*, 1993).

TREES	COMMON NAMES
Abies lasiocarpa	subalpine fir
Larix occidentalis	western larch
Picea	spruce
Pinus contorta	lodgepole pine
SHRUBS	
Alnus sinuata	sitka alder
Kalmia microphylla	small-leaved laurel
Ledum glandulosum	labrador-tea
Linnaea borealis	twinflower
Lonicera utahensis	Utah honeysuckle
Menziesia ferruginea	fool's huckleberry
Rubus parviflorus	thimbleberry
Spiraea densiflora	subalpine spiraea
Vaccinium globulare	globe huckleberry
Vaccinium myrtillus	dwarf huckleberry
Vaccinium occidentale	western huckleberry
GRAMINOIDS	
Agrostis scabra	tickle-grass
Alopecurus aequalis	short-awn foxtail
Calamagrostis canadensis	bluejoint reedgrass
Carex canescens	gray sedge
Carex disperma	soft-leaved sedge
Carex lenticularis	lentil-fruited sedge
Carex limosa	mud sedge
Carex rostrata	beaked sedge
Carex scopulorum	Rocky Mountain sedge
Eleocharis palustris	common spikesedge
Eriophorum chamissonis	Chamisso's cotton-grass
Juncus ensifolius	dagger-leaf sedge
Glyceria borealis	northern mannagrass
Glyceria striata	fowl mannagrass
Luzula parviflora	small-flowered woodrush

FORBS	COMMON NAMES
Chimaphila umbellata	common prince's pine
Cicuta douglasii	douglas water-hemlock
Dodecatheon jeffreyi	Jeffrey's shooting star
Drosera rotundifolia	roundleaf sundew
Goodyera oblongifolia	rattlesnake plantain
Habenaria saccata	slender bog-orchid
Hieracium albiflorum	white-flower hawkweed
Hypopitys monotropa	pinesap
Ligusticum spp.	lovage
Listera cordata	heart-leaf twayblade
Menyanthes trifoliata	buckbean
Nuphar polysepalum	spatter-dock
Pedicularis racemosa	sickletop lousewort
Potamogeton amplifolius	large-leaved pondweed
Potentilla palustris	purple cinquefoil
Pterospora andromedea	pinedrops
Pyrola asarifolia	pink wintergreen
Pyrola picta	white-vein wintergreen
Pyrola secunda	one-sided wintergreen
Senecio serra	tall butterweed
Spagnum argustifolium	
Spagnum mendocinum	
Spiranthes ramonzoffiana	hooded ladies-tresses
Tiarella trifoliata	foamflower
Viola orbiculata	round-leaved violet
Viola palustris	marsh violet
Xerophyllum tenax	beargrass
FERNS and FERN ALLIES	
Dryopteris filix-mas	male fern
Equisetum arvense	field horsetail
Lycopodium annotinum	stiff clubmoss

Table 1. Present-day vascular plants identified on or around Marys Pond, Montana. List compiled by U.S. Region 1 Forest Service botanist.

METHODS

Data Collection

Sediment cores were collected from Marys Pond in August and November of 1985 in a cooperative agreement between Washington State University, Pullman, WA and the U. S. Forest Service, Intermountain Research Station. Sediments from the center of the pond were recovered with a modified Livingston piston corer and drive tower supported by a plywood raft (Cushing and Wright, 1965). The core barrels are made of a 10 cm (4 inch) diameter PVC pipe. Two overlapping cores (0.00 to 1.46 m and 0.35 to 2.05 m) from the center of the pond were taken to ensure an uninterrupted sediment record.

The sediments were exposed for cleaning and sampling by splitting the core barrels lengthwise with a circular saw. The cores held tephra from eruptions of Mount Mazama and Glacier Peak (Foit *et al*, 1993). Paired samples were taken by packing sediment into a 0.5 teaspoon scoops equaling a volume of 2.3 cm^3 (Fletcher and Clapham, 1974). Samples were extracted every five centimeters from the two adjacent overlapping cores to attain a continuous pollen record from the most recent deposits down to Mazama tephra. Sixty centimeters of the top most core were sampled with an additional 125 centimeters coming from the deeper core. I extracted 46 samples (thirteen from the top most core and thirty-three from the deeper core). This allows for an overlap of thirty-five centimeters with which to correlate the two cores and attain an uninterrupted pollen record to Mazama tephra at 2.00 m (Figure 2).

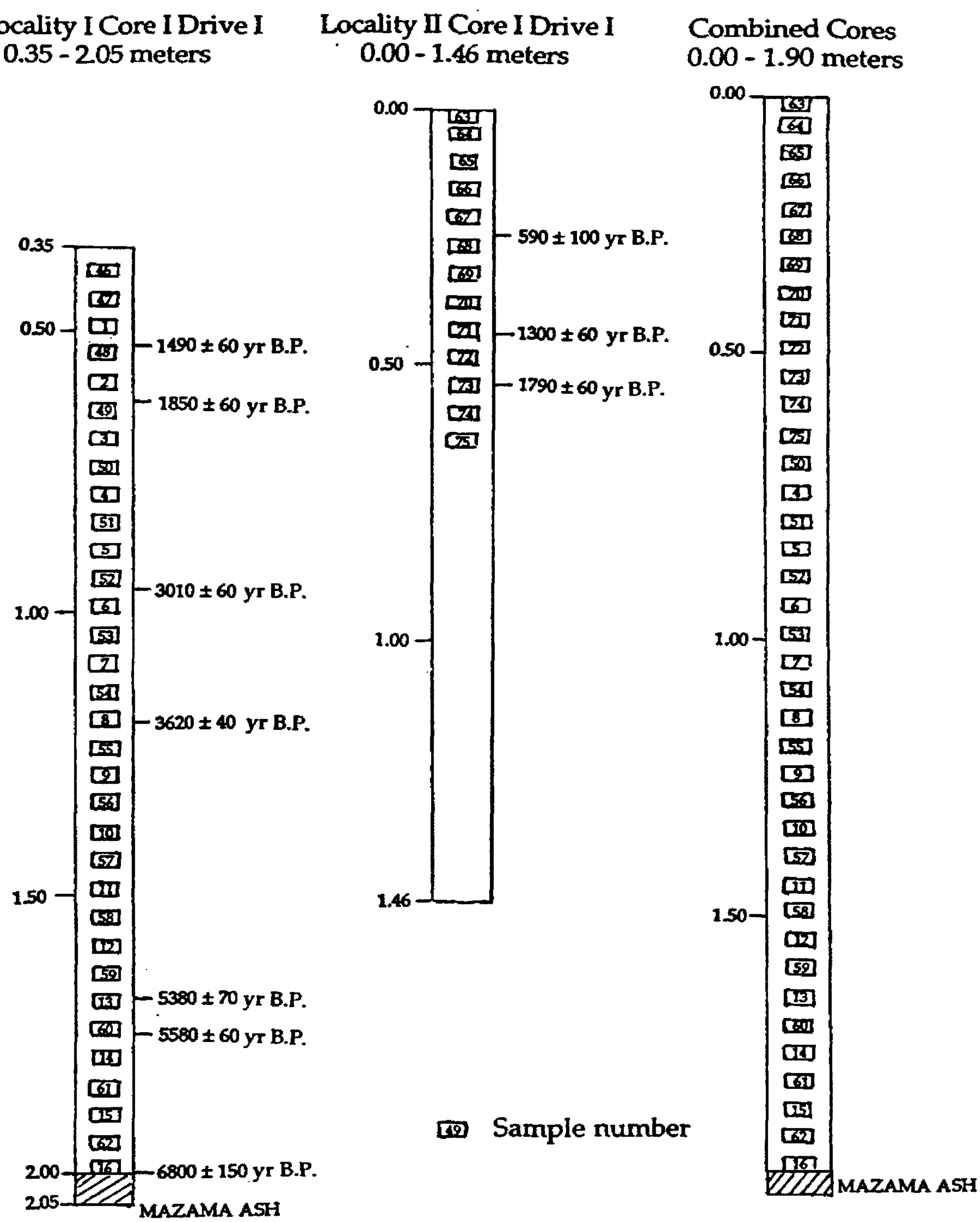

Figure 2. Illustration of how the two sediment cores were sampled and combined to create one continous record. Dates along the length of the cores correspond to the ^{14}C ages obtained from macrofossils found within the sediments.

One of each paired sample was used to determine percentage organic carbon by weight loss on ignition. The dry weight of the samples was reported, then each was burned at 600° C for at least 24 hours, cooled in a desiccator, and weighed on a Mettler balance. The resulting weight loss gives a measure of organic carbon in the sediment samples (Dean, 1974).

The concentration estimates of pollen and charcoal per cubic centimeter were determined by adding a known quantity of Lycopodium spores to the sample (10,850 ± 200 in each of 20 tablets, Batch 006720 for samples 1-16; 13,911 ± 308 in each of 10 tables, Batch 710961 for samples 46-75) (Davis 1969; Stockmarr 1971). The samples were deflocculated in distilled water, mixed with weak HCl and stirred on magnetic vortex mixers. The samples were washed through 100 mesh per inch screen to remove extraneous debris. Calcium carbonates, humic acids, siliceous matter and cellulose were removed with additional HCl, KOH treatment, HF and acetolysis. The samples were stained with Safrinin O, and mounted in 2000 cs silicon oil (Faegri and Iversen, 1989).

In order to determine the sequence of compositional changes in time, a chronological framework is established through radiocarbon dates taken from organic fossils found within the core samples. Tephra lenses often provide a time scale in the Pacific Northwest. The cores from Marys Pond hold the 6850 B.P. Mazama ash from Crater Lake Oregon (Bacon, 1983). To further refine the chronology of the pollen core, nine macrofossil samples were removed from the sediments to be used for accelerator radiocarbon dates. These included six Pinus contorta needles, one sample of Sphagnum sp., Nuphar sp. seeds and a large charcoal fragment. The samples were dated through the

Institute of Arctic and Alpine Research, Laboratory for Accelerator Radiocarbon Research at the University of Colorado, Boulder.

The two overlapping cores were correlated to one another through visual inspection of the sediments, radiocarbon dates and using the resulting pollen diagrams. As a result, the top of Locality II, Core I, Drive I is considered zero centimeters (the top of the pond sediments) and the bottom of Locality I Core I Drive I is 190 cm below surface with the upper contact of Mazama tephra. I used thirteen samples from Locality II, Core I, Drive I. The top seven samples from Locality I, Core I, Drive I were not used because of the overlap. The results and discussion that follow will consider the two combined cores as a single record of thirty-nine samples (Figure 2).

Pollen and Data Analyses

At least 500 terrestrial pollen grains were counted for each of the 46 samples at 400X magnification. Spores, acid-resistant algae and charcoal fragments were also tallied. Pollen and spore identifications were confirmed by comparison with the pollen reference collection at Washington State University. Charcoal fragments were counted and measured along the longest axis in three size classes; 25-50μm, 50-100μm, and >100 μm, following Mehringer *et al*,, 1977a.

Pollen counts were used to generate a relative frequency pollen diagram. The resulting pollen diagram contains all the identified taxa organized by arboreal species, shrubs, forbs, aquatic plants, spores, and algae (Figure 3). Other pollen diagrams include ratios of nonarboreal pollen (NAP) to arboreal pollen (AP), ratios and percentage diagrams of specific conifers, and pollen accumulation rates per centimeter squared per year.

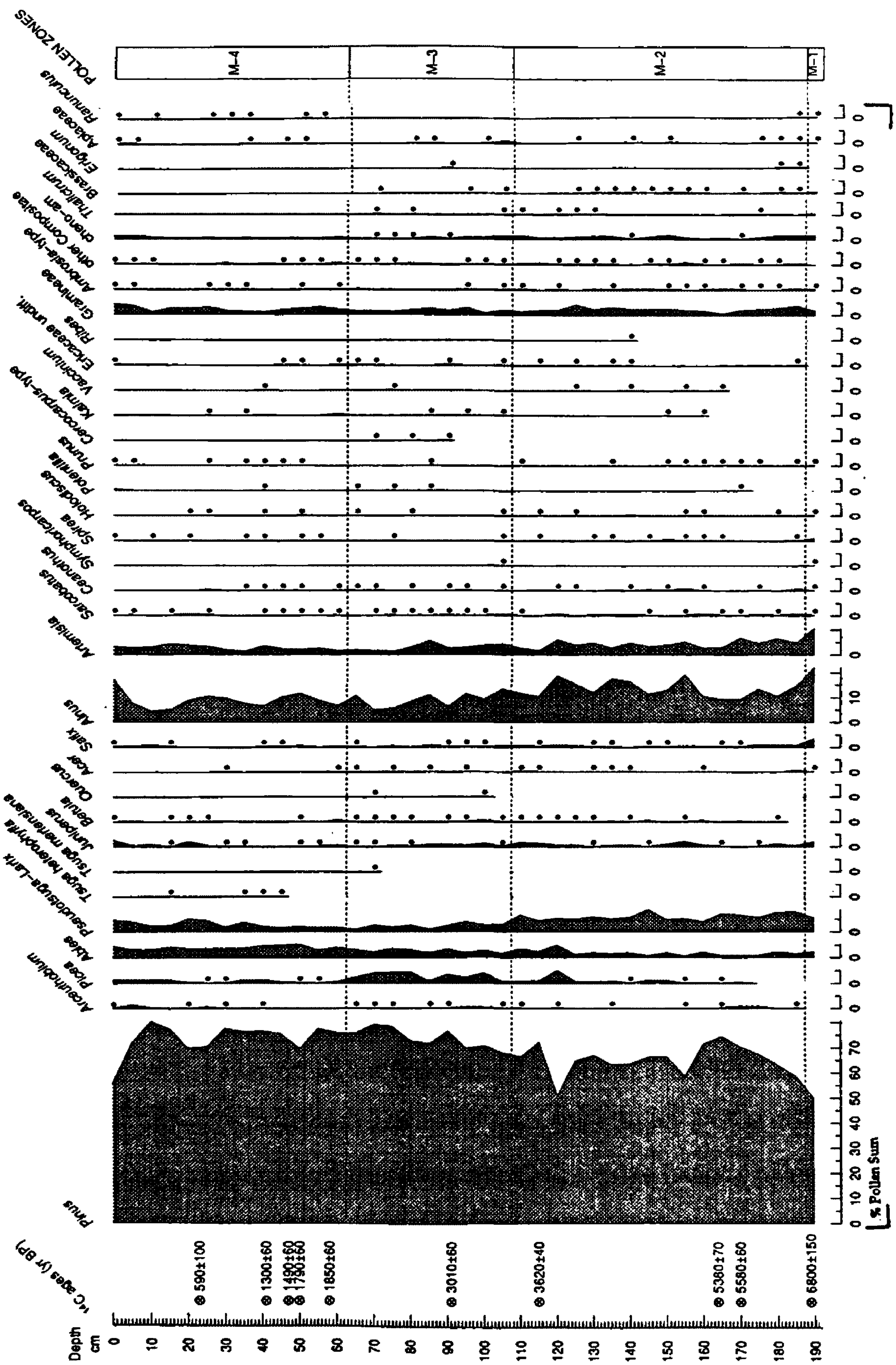

Figure 3. Relative percentage pollen, spore and microfossil diagram from Marys Pond, 1750 meters, Bitterroot Mountains, Montana. ● = <0.5%.

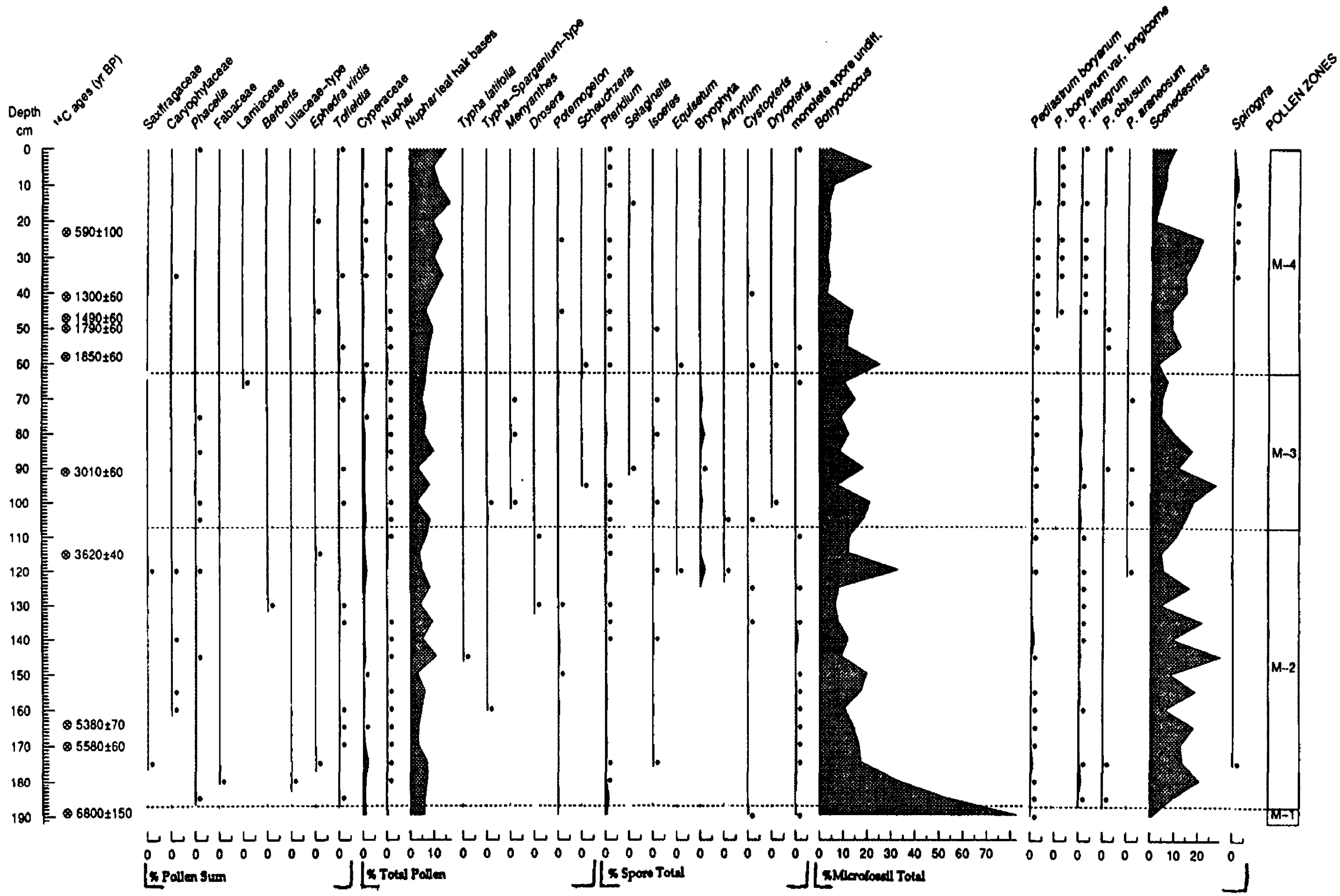

Figure 3 (cont.). Relative percentage pollen, spore and microfossil diagram from Marys Pond, 1750 meters, Bitterroot Mountains, Montana. • = <0.5%.

Four pollen zones were delineated using psimpoll 2.23 (Bennett, 1994), a pollen data analysis computer program. The program divides the zones by agglomeration using constrained cluster analysis developed by Grimm (1986). This method is based on the constraint that the data must be clustered by stratigraphically adjacent samples. Four ubiquitous taxa, Pinus, Alnus, Botryoccus and Scenedesmus were removed from the data set for zonation purposes. These four taxa have a large ecological amplitudes and only serve to over shadow those species that might better delineate zones.

Total pollen and charcoal accumulation rates were calculated for Marys Pond sediments. Pollen and charcoal accumulation rates estimate the annual deposition of the taxon independent of all other pollen types and varying sedimentation rates (Davis, 1969; Birks and Gordon, 1985). The concentration of the indigenous pollen is estimated in proportion to the number of Lycopodium counted.

I analyzed microscopic charcoal through ratios of charcoal to total terrestrial pollen and charcoal accumulation rates $cm^{-2} yr^{-1}$. The accumulation rate of the three charcoal size classes referenced above are separated and accentuate further differences in fire history through time.

RESULTS

Sediments and Chronology

Radiocarbon dates range from 590 $\pm$ 100 yr B.P. at 23 cm, to 5580 $\pm$60 yr B.P. at 170 cm. I placed the basal date at 6800 $\pm$150 yr B.P. in accordance with the age of the Mount Mazama eruption (Bacon, 1983). To determine sedimentation rates, the radiocarbon dates were "calibrated" to accommodate temporal variations in the ^{14}C content of atmospheric carbon dioxide

(Stuiver and Reimer 1993). Table 2 shows the ^{14}C dates attained from macrofossils, their respective depths, source, and the calibrated dates. The "calibrated" radiocarbon dates were used to determine sedimentation rate. A graph plotting depth to age of both "conventional" and "calibrated" radiocarbon dates shows that the deposition rate of the sediments was relatively constant throughout the length of the core (Figure 4).

DEPTH (m)	^{14}C AGE YR B.P.	MATERIAL DATED	CALIBRATED ^{14}C DATE
0.23	590 ± 100	*Nuphar* sp.. seeds	618 yr B.P.
0.41	1300 ± 60	*Pinus contorta* needle	1259 yr B.P.
0.47	1490 ± 60	*Pinus contorta* needle	1366 yr B.P.
0.50	1790 ± 60	*Sphagnum* sp..	1706 yr B.P.
0.58	1850 ± 60	*Pinus contorta* needle	1815 yr B.P.
0.91	3010 ± 60	Charcoal fragment	3205 yr B.P.
1.15	3620 ± 40	*Pinus contorta* needle	3955 yr B.P.
1.64	5380 ± 70	*Pinus contorta* needle	6264 yr B.P.
1.70	5580 ± 60	*Pinus contorta* needle	6397 yr B.P.
1.90	6800 ± 150	Mazama tephra	7604 yr B.P.

Table 2. Marys Pond radiocarbon dates.

The percent organic content of the sediment (measured by weight per volume of sediment) is greatest above 30 cm depth and gradually declines below that point (Figure 5). Two samples mark a dramatic contrast to the diagram at 105 cm and 125 cm. The percent organic content drops from 36% to 20 % and 34% to 20% respectively. These declines in organic content correspond with increases in charcoal accumulation.

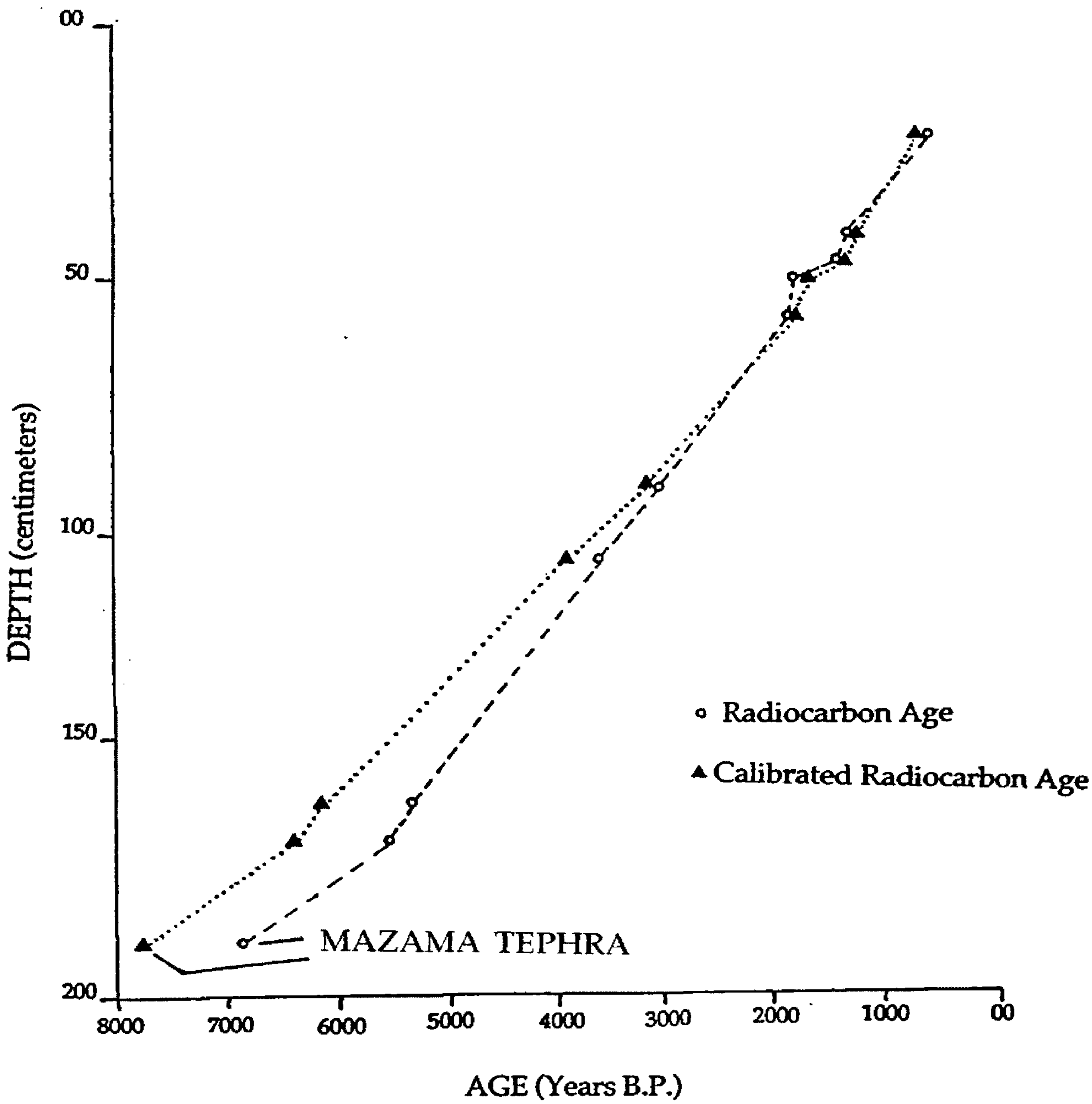

Figure 4. Distribution of radiocarbon dates and their calibrated age (Table 1) for 190 centimeters of the Marys Pond cores above Mazama tephra. The radiocarbon dates are derived from macrofossils extracted from the sediment cores. The calibrated radiocarbon dates come from Stuiver and Reimer, 1993.

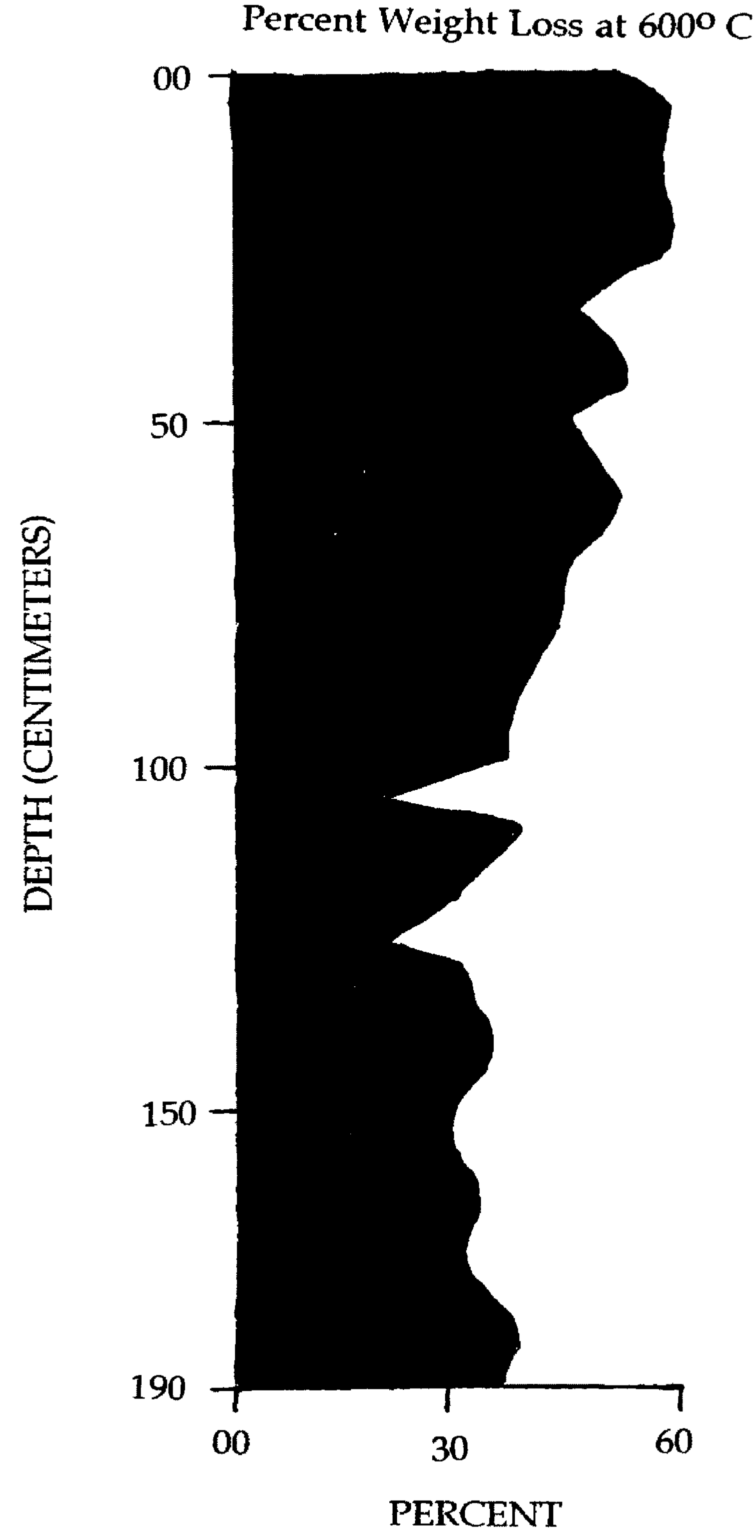

Figure 5. Percent organic carbon in samples after combustion at 600° C. Declines at 1.05 m and 1.25 m correspond with a sharp increases in relative abundance of microscopic charcoal.

Relative Frequency Diagram

Figure 3 displays the relative frequencies of the most common pollen, spores and acid resistant algae in the analyzed sediment core from Marys Pond. The relative frequency of the taxa is calculated as follows: "pollen sum" includes all terrestrial pollen excluding Cyperaceae (sedge family), "total pollen" indicates the percent of all terrestrial pollen, Cyperaceae and aquatic plants, "spore total" adds spores to the terrestrial and aquatic taxa, and "microfossil total" encompasses all pollen, spores and acid resistant algae. The division of taxa into these various totals places the primary interest on regional vegetation. Pollen that originated from the upland vegetation are therefore included in the pollen sum. Birks and Gordon (1985) suggests that local lowland aquatic vegetation be excluded for they are site specific and represent a different vegetation from the primary objectives of this study. A dot on the diagram represents a relative frequency of less than 0.5%.

Pollen of Terrestrial Species

Pinus (pine) pollen dominates the relative frequency diagram representing up to 80% of the terrestrial grains in the recent portion of the sediment core. A distinction between diploxylon (P. contorta and P. ponderosa) and haploxylon (P. albicaulis, P. monticola, P. flexilis) pine was made when possible. Diploxylon grains dominate haploxylon consistently throughout the pollen record (Figure 6).

Other conifers includes Picea (spruce), Abies (fir), Tsuga heterophylla, Tsuga mertensiana (mountain hemlock) and Pseudotsuga/Larix (Douglas-fir, larch) (Figure 3). Pseudotsuga and Larix are grouped as one taxa since the

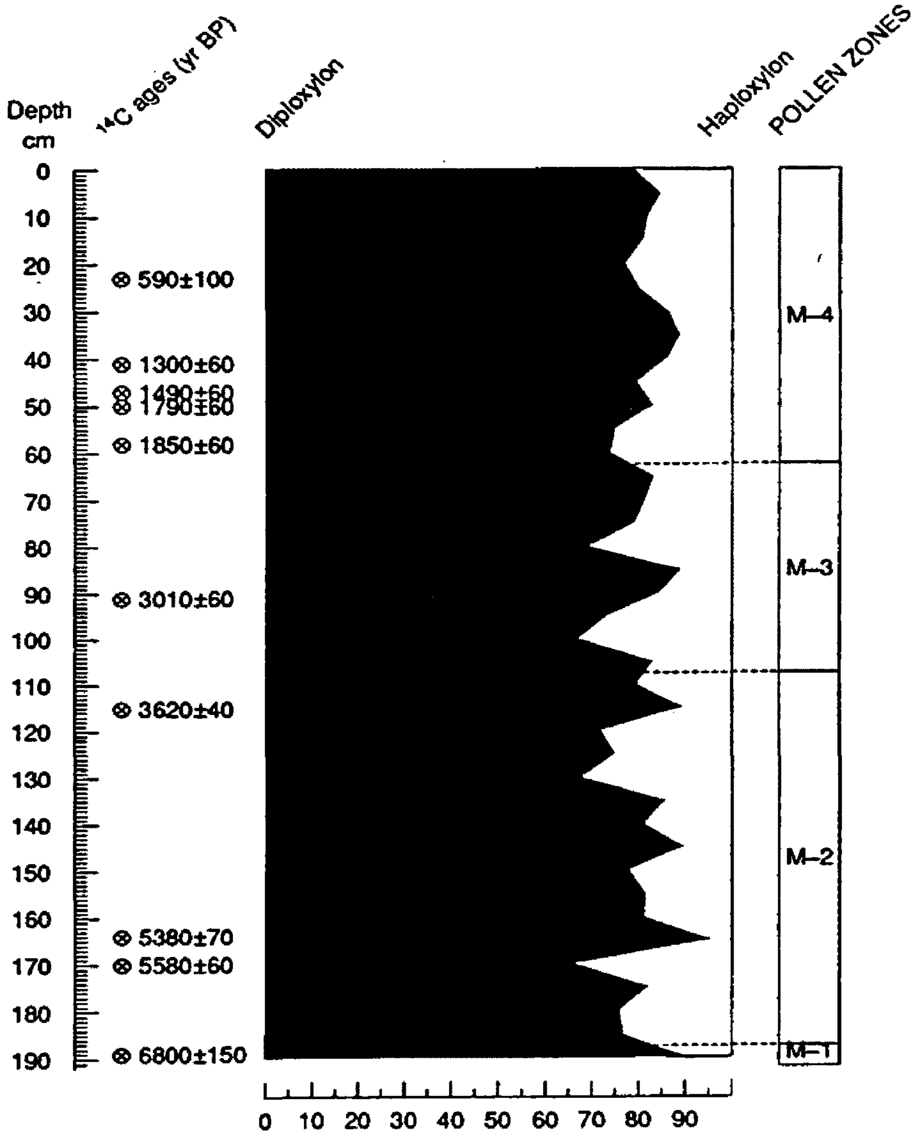

Figure 6. Relative percent of diploxylon to haploxylon pine pollen at Marys Pond, Montana.

pollen grains are not morphologically distinct enough from one another to be separated. Larix occidentalis is a significant component of the stands surrounding Marys Pond today. Still, Pseudotsuga is a common contributor to the elevation and habitat type of the immediate area (Pfister *et al.*, 1977).

Abies shows a gradual percentage increase in frequency as the sediments approach the present, reaching its maximum frequency after 2000 yr B.P. Pseudotsuga/Larix exhibits the opposite trend with its greatest frequency occurring at the deepest part of the core between 110 cm to 190 cm (3500 yr B.P. to 6800 yr B.P.) and decreasing towards the present-day. Picea first appears in the pollen record at a depth of 180 cm, corresponding to approximately 5800 yr B.P. (Figure 3). Tsuga heterophylla occurs four times in the pollen record at depths of 15 cm, 35 cm, 40 cm and 45 cm while Tsuga mertensiana occurs once at a depth of 70 cm. Tsuga heterophylla does not appear in the pollen record until after 2000 yr B.P. In each case, it represents less than 0.5% of the total terrestrial pollen and probably blew in from other areas.

The most abundant nonarboreal species are Alnus and Artemisia. Alnus is a prolific pollen producer averaging approximately 10% of the total terrestrial pollen and never dips below 5% of the pollen sum throughout the length of the core. Artemisia remains a constant background component of the vegetation as it is an important taxa from lower elevations and blows in from other regions. Both of these taxa reached their highest percentage at the base of the core: Alnus at 22% and Artemisia at 11%.

Juniperus, Betula, Ceanothus and Salix all occur with some regularity, but rarely represent more than 0.5% of the total pollen. Other shrub species that are present sporadically include Kalmia, Vaccinium, Spirea, Holodiscus, Acer, Prunus, Berberis, and Ribes.

Gramineae and Cheonpodiineae (cheno-ams) are two additional taxa which appear with some frequency throughout the pollen diagram. Gramineae averages approximately 2% of the relative pollen frequency with its highest occurrence soon after Mazama ash at 4%. Chenopodiineae is often present at about 1% with its highest showing of 2% at the base of the core. Both families are prolific pollen producers and can disperse pollen over great distances. At least four grass species are currently present at Marys Pond.

The pollen record from Marys Pond contains a wide assortment of forbs throughout the core. Many of these are insect pollinated plants which indicate a close proximity of these taxa to the site. I observed the following genera and families: Compositae, Ranunculus, Primulaceae, Saxifragaceae, Ericaceae, Thalictrum, Cruciferae, Erigonum, Umbelliferae, Liliaceae, Tofieldia, Phacelia, Leguminosae, and Labiatae. At least two species of Compositae and Umbelliferae, three species of Rosaceae and eleven species of Ericaceae are present at the pond today (Table 1). Ephedra virdis-type is probably transported from the northern Great Basin and its pollen is present in three of the samples counted.

Pollen of Aquatic, Pond Edge and Fen Species

The aquatics include obligate aquatic plants and bog and fen species. At Marys Pond these include Cyperaceae, Nuphar, Typha latifolia, Menyanthes, Drosera, Potemogeton and Scheuchizeria. Cyperaceae averages 1% of the pollen frequency consistently throughout the pollen core. Nuphar pollen occurs with regularity (at less than 0.5%) along the length of the pollen record.

Nuphar leaf hair base cells are also present and in greater quantity than Nuphar pollen. Due to their abundance, the leaf hair cells may provide a more complete representation of the plant (Warner, 1990).

Spores

The spores are represented by ferns, mosses, horsetail and mistletoe. Pteridium, Arthyrium, Cystopteris, and Dryopteris spores occur periodically with Pteridium being the most common of the ferns. Bryophyta (mosses) are not present in the pollen record until 120 cm depth (3800 yr B.P.) at which point they reach a peak of 2% of the spore total. Equisetum (horsetail) occurs twice at a depth of 120 cm and again at 60 cm depth. Arceuthobium (mistletoe) is present with some regularity throughout the pollen core. There are various species of Arceuthobium which are parasitic on Pinus, Abies, Pseudotsuga menziesii, Larix, Thuja or Picea (Hitchcock and Cronquist, 1981). I could not distinguish between the three possible contributors of Arceuthobium.

Algae

The acid resistant algae are represented by five species of Pediastrum, Botryococcus, Scenedesmus and Spirogyra. The five Pediastrum species occur sporadically throughout the pollen core with the most consistent being Pediastrum boryanum. Pediastrum generally live on the bottoms of quiet pools and lakes (Bold *et al.*, 1987). Botryococcus show at least five distinctive peaks in the relative frequency diagram. These occur at 5 cm, 40-50 cm, 100 cm, 120 cm and 190 cm depth. The greatest increase is at 190 cm (following the fall of Mazama ash) where 2585 individual Botryococcus were counted.

The increases at 100 cm and 120 cm (21% and 33%, respectively) occur directly after a dramatic increase in charcoal frequency. The Scenedesmus is quite abundant throughout much of the core with an average of 10% and a high of 30% at 145 cm depth. Scenedesmus are considered ubiquitous, occurring abundantly in many freshwater habitats (Bold *et al.*, 1987). Spirogyra is not as well represented with a trace noted at 175 cm depth and not again until 30 cm depth and continuing through the top of the core.

Pollen / Charcoal Accumulation Rates

The pollen accumulation at the bottom of the core begins at almost 10 x 10^3 grains $cm^{-2}\,yr^{-1}$, but quickly falls to around 6.5 x 10^3 grains $cm^{-2}\,yr^{-1}$ at 185 cm depth. Between 6000 and 2000 yr B. P. the pollen accumulation rate displays relatively large and regular fluctuations. These vary between 9.9 x 10^3 grains $cm^{-2}\,yr^{-1}$ at 90 cm depth, to 3.7 x 10^3 grains $cm^{-2}\,yr^{-1}$ at 120 cm depth. The greatest pollen accumulation rate occurs at 70 cm (approximately 2100 yr B.P.) with a value of 12 x 10^3 grains $cm^{-2}\,yr^{-1}$. After 2000 yr B.P., the pollen accumulation falls, finally wavering around 5.5 x 10^3 grains $cm^{-2}\,yr^{-1}$ in the most recent portion of the core.

The charcoal accumulation rate has less fluctuation than the pollen except in two quite noticeable places. At 125 cm depth, the accumulation makes a dramatic leap from 1 x 10^3 $cm^{-2}\,yr^{-1}$ to 46 x 10^3 $cm^{-2}\,yr^{-1}$ charcoal fragments. This peak occurs at approximately 4000 yr B.P. The charcoal accumulation rate drops back to about 1.1 x 10^3 grains $cm^{-2}\,yr^{-1}$ at 120 cm depth, then jumps again to 16 x 10^3 grains $cm^{-2}\,yr^{-1}$ at a depth of 105 cm (around 3300 yr B.P.). From 0 cm to 60 cm (approximately the last 2000 yr B.P.), the accumulation rate averages around 2.1 x 10^3 grains $cm^{-2}\,yr^{-1}$.

Ratios

Ratios of charcoal to total terrestrial pollen further exemplifies the tremendous amount of charcoal deposited in the sediments at the two localities described above. At 125 cm depth the ratio of charcoal to terrestrial pollen shifts from 0.2 to 6.7 (a larger value indicating greater charcoal to pollen). Another jump occurs at 105 cm with an increase of charcoal to terrestrial pollen increases from 0.3 to 2.7. The ratio of charcoal to terrestrial pollen throughout the remainder of the sediment core averages 0.25. The ratio at the top of the core is 0.5 (Figure 11).

The ratio of nonarboreal pollen (NAP) to arboreal pollen (AP) illustrates the dominance of Pinus throughout much of the core. The AP pollen dominates the NAP consistently through the pollen record except for the period directly following the fall of Mazama ash. Here the ratio reflects the dominance of NAP at a ratio of 0.8. After this initial dominance of NAP, the AP consistently exceeds the overall pollen record at Marys Pond by factors ranging from 0.05 to 0.4 (Figure 7).

Pollen Zones

Four pollen zones were delineated from the core for ease in the discussion and interpretation of the pollen assemblage (for a discussion on how zones were determined see Methods). The zones represent "a body of sediment distinguished from adjacent sediment bodies by differences in kind and amount of its contained fossil pollen grains and spores, which were derived from plants existing at the time of deposition of the sediment" (Birks and Gordon, 1985). Zone I is from 190 cm to 188 cm corresponding to about 6800 yr B.P. to 6500 yr B.P. Zone II ranges from 188 cm to 108 cm, a span dating

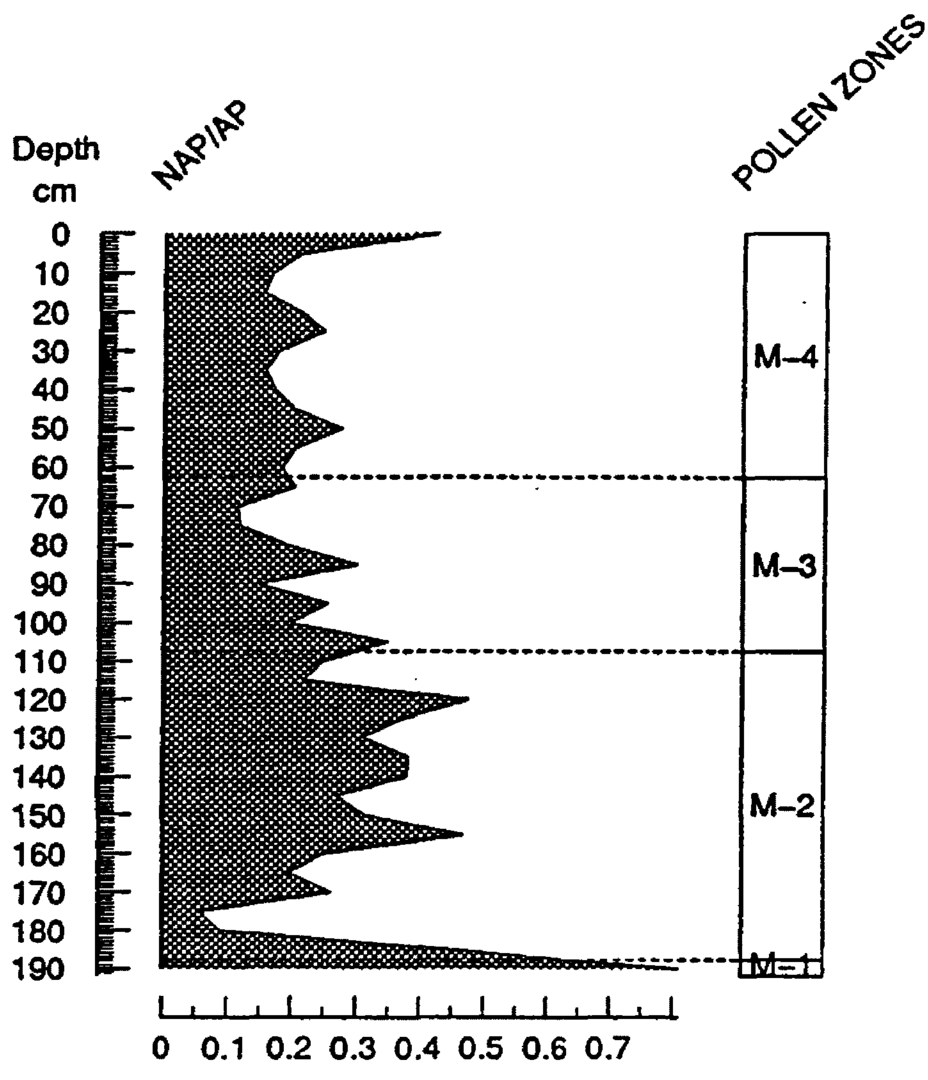

Figure 7. Ratio of NonArboreal Pollen (NAP) to Arboreal Pollen (AP).

from 6500 yr B.P. to 3500 yr B.P. The third zone covers approximately 1500 years (3500 yr B.P. to 2000 yr B.P.) extending from 108 cm to 63 cm. Zone IV is the most recent zone ranging from 2000 yr B.P. to the present (63 cm to 0 cm).

DISCUSSION

Marys Pond was cored with the expectation that it would provide a continuous record of the origins and progressive pathways of the past 6800 years which have resulted in the present-day plant community. Pollen is well preserved in the sediments facilitating the identification and successive collection of the pollen assemblage. Charcoal fragments are present and quantified for fire history interpretations. An accompanying chronology was generated from in situ macrofossils from radiocarbon dates. Thus, with good pollen and charcoal preservation, and an adjoining time frame, the following interpretation of the core is presented.

Vegetation and Climate

Post Mazama: 6800-6200 yr B.P. *(Zone I)*

The most outstanding feature of this zone is the dominance of NAP over AP (a ratio of 0.8). This it the only place in the pollen record where NAP over shadows the AP. This results from the simultaneous abundance of Alnus, Artemisia, cheno-ams, Gramineae, and Spirea following the fall of Mazama ash. Also noteworthy is an abundance of Juniperus and Salix, plus aquatic related species including Cyperaceae, Nuphar, Botryoccus and Pteridium. A similar increase in shrubs and forbs is observed at Sheep Mountain Bog. In particular, an abundance of Physocarpus is apparent just above and below Mazama ash (Mehringer, 1985).

It is tempting to relate this particular species composition to the influence of Mazama ash, however, other studies suggest that ashfalls have little effect on regional vegetation. At Lost Trail Pass Bog, Mehringer *et al.* (1977a), found no indication of vegetation or pollen production being influence by the ashfall. Since no samples were analyzed directly below Mazama ash at Marys Pond, the impact of Mazama tephra on the surrounding vegetation remains a mystery.

Botryoccus deserves special mention since it accounts for 82% of all the pollen and microfossils in the sample directly above Mazama ash. At Lost Trail Pass, Botryoccus and Pediastrum were used to deduce the season of Mazama ashfall (Mehringer *et al.*, 1977b). Samples below and above Mazama ash contained 4300 to 6000 of these algae per squared centimeter per year. However, samples taken of Mazama ash contained only 358 Botryoccus and Pediastrum specimens. Mehringer *et al.* (1977b), conclude that during the nearly three years of redeposition of Mazama tephra had a profound effect on the productivity of Lost Trail Pass Bog. However, the effects were short term and may have even increased vigor and pollen production. Perhaps the superabundance of Botryoccus at Marys Pond resulted from a short term effect of Mazama tephra.

Pseudotsuga/Larix: 6200-3500 yr B.P. *(Zone II)*

This zone corresponds with the geological time period termed the middle Holocene. During this period, "without exception", the paleoecological record has shown a warming throughout the interior Pacific Northwest and northern Great Basin (Mehringer, 1985). A ternary diagram of the pollen from three conifers, Picea, Abies and Pseudotsuga/Larix is presented (Figure 8). These three species were chosen because they are the best indicators of climate and/or site conditions of the dominate life forms represented by pollen. The diagram unmistakably illustrates the dominance of Pseudotsuga/Larix over the other two genera during this time. The dominance of Pseudotsuga/Larix over Picea and Abies suggests a time of higher temperatures and perhaps less effective moisture.

This same phenomenon occurred at Lost Trail Pass Bog with an increase in Pseudotsuga/Larix pollen and diploxylon pines (probably lodgepole pine) replacing haploxylon pines (possibly the more cold tolerant whitebark pine) (Mehringer *et al.*, 1977a). The prevalence of Pseudotsuga/Larix is further illustrated in the relative percentage diagram of these three conifers (Figure 9).

A general overview of the percentage pollen diagram in Zone II indicates presence of a fairly consist variety of taxa. Six taxa occur only in Zone II: Caryophylaceae, Berberis, Ribes, Liliaceae, Typha latifolia and Drosera. Although not found in great quantities, the pollen from Ambrosia-type, other Compositae, Ceanothus, Spirea, Cruciferae, Umbelliferae and Prunus-type occur consistently in this zone. This may all indicate relative diverse plant communities during this period.

Mixed Species: 3500-2000 yr B.P. *(Zone III)*

The ternary diagram of Pseudotsuga-Larix, Picea and Abies for this time period shows a shift in the dominate plant community to a more mixed species composition (Figure 8). In general there appears to be about the same relative abundance of these three conifers. This might indicate a climatic change towards cooler temperatures and more effective moisture relative to

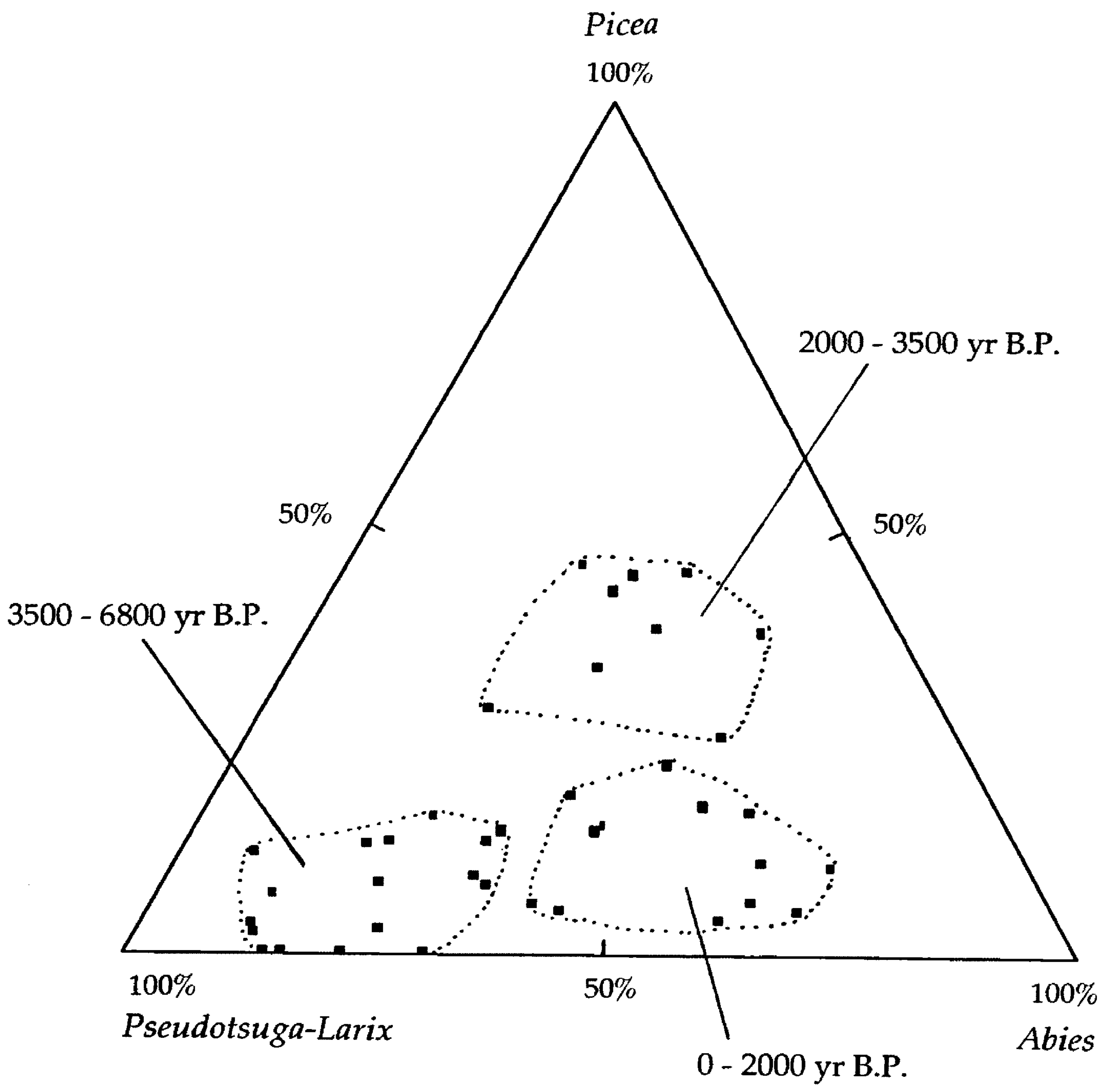

Figure 8. Ternary plot of Picea, Abies and Pseudotsuga-Larix pollen for the past 6800 years from Marys Pond, Montana. Dots represents the relative abundance of all three taxa at each of the 39 samples. Samples that fall within each particular time period are circled. This illustrates how the composition of these conifer taxa have shifted through time.

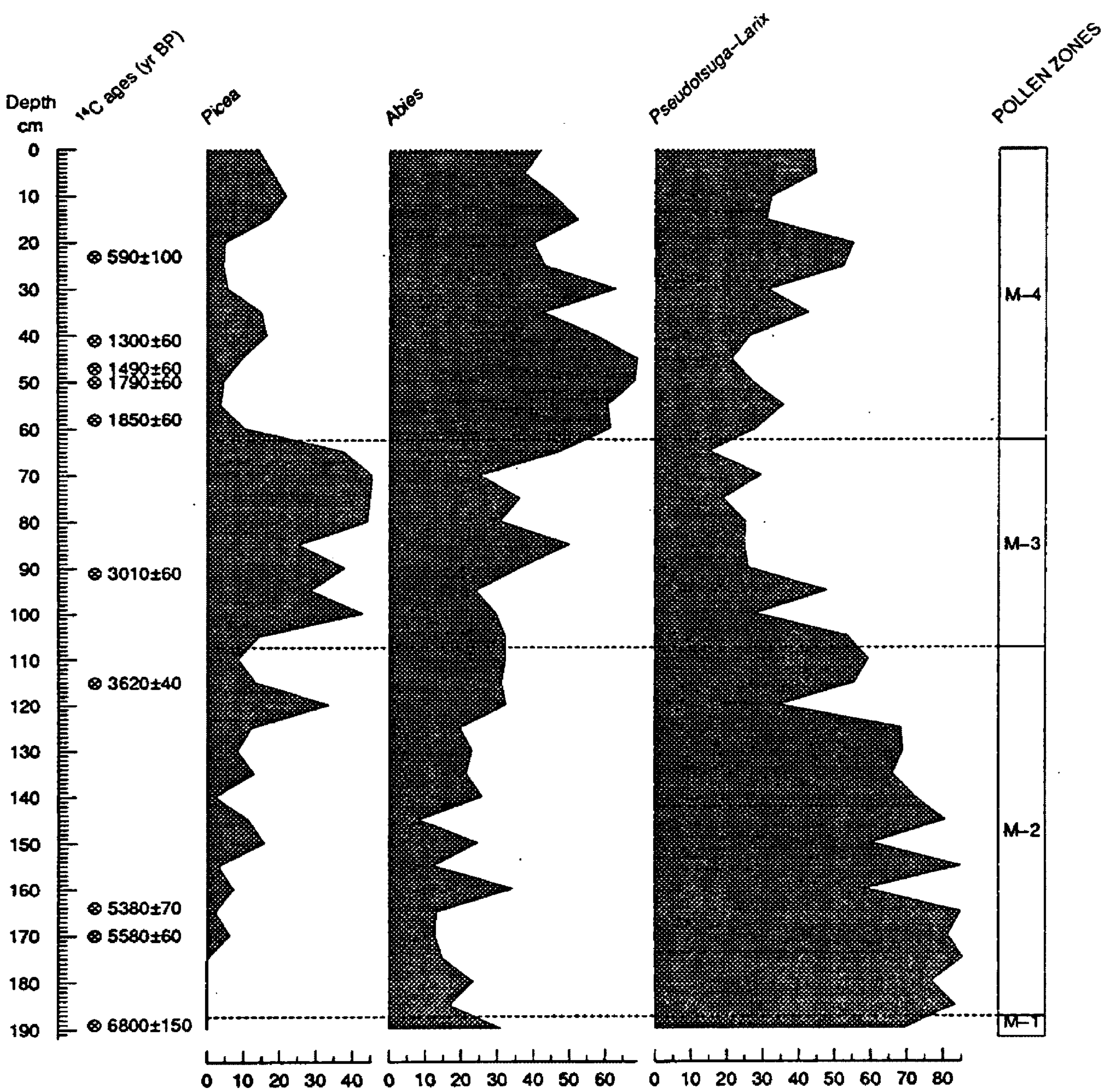

Figure 9. Relative percentage diagram of Picea, Abies and Pseudotsuga-Larix. (%Picea + %Abies + %Pseudotsuga-Larix = 100%)

Zone II. A ratio of Picea and Abies (indicators of cooler temperatures and more effective moisture) to Pseudotsuga-Larix (warmer, drier conditions) shows the greatest values in Zone III (Figure 10). Whereas ratios of Picea and Abies to Pseudotsuga-Larix range from 0.17 to 1.9 in Zone II (suggesting the dominance of Pseudotsuga-Larix), ratios in Zone III range from 0.9, to a high of 5.7 (indicating the dominance of Picea and Abies).

This apparent shift towards cooler and moister conditions was also reported at both Smeads Bench Bog and Lost Trail Pass Bog (Chatters and Leavell, 1994; Mehringer *et al.*, 1977a) At Smeads Bench Bog, this period corresponds with a closed canopy forest interpreted to be an Abies grandis habitat type (Chatters and Leavell, 1994). This habitat type indicates a moist site with a maritime-influenced climate (Pfister *et al.*, 1977). At Lost Trail Pass Bog, the Pseudotsuga has greatly declined by 4000 yr B.P. and there is a marked increase in diploxylon pine and haploxylon pine (presumably whitebark pine). Mehringer *et al.* (1977a), interpret this as a climatic shift indicative of more effective moisture.

The number of different species remains relatively high as in Zone II with the addition of Primulaceae, Menyanthes and Scheuchzeria. This zone also contains the widest variety of spores.

Present-day: 2000 yr B.P.-Present *(Zone IV)*

Zone IV represents the most recent time period and seems to correlate with the plant community present at Marys Pond today. The ternary diagram reveals another shift of the conifer composition towards a preponderance of Abies and Pseudotsuga/Larix (Figure 8). The relative frequency diagram of these three conifers clearly shows the decline of Picea, the dominance of Abies

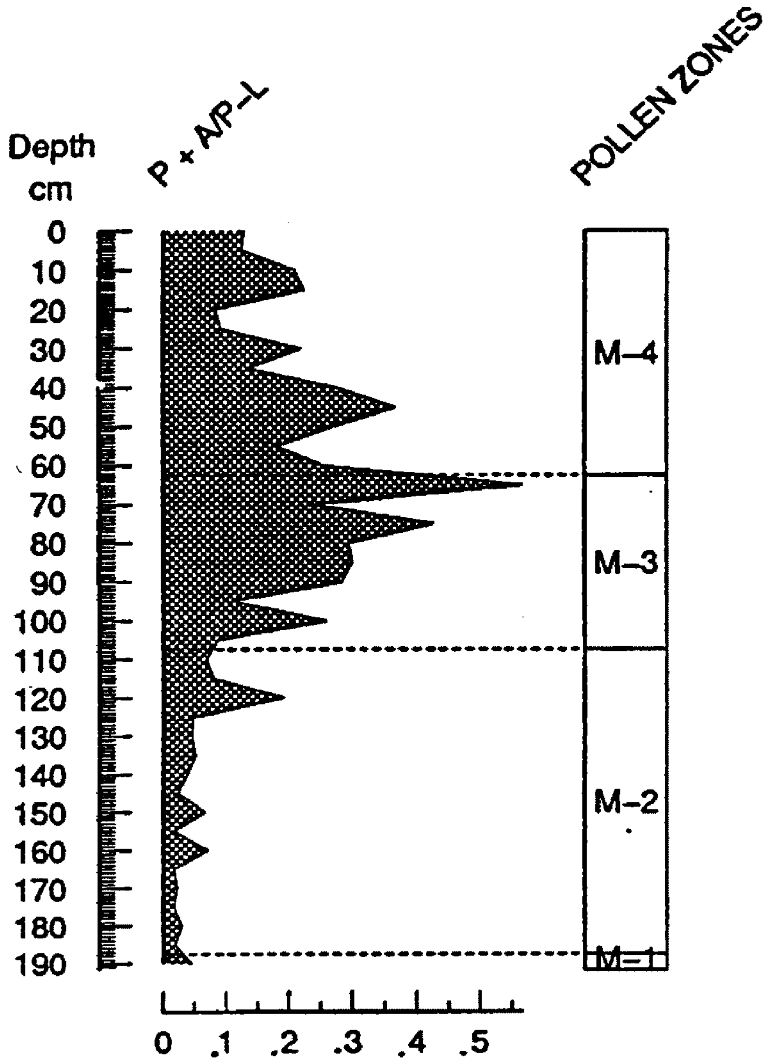

Figure 10. Ratio of Picea and Abies pollen (indicators of cooler temperatures and more effective moisture) to Pseudotsuga/Larix pollen (indicator of warmer, drier conditions). P + A = sum of Picea and Abies; P - L = Pseudotsuga/Larix.

and co-dominance of Pseudotsuga/Larix (Figure 9). Presently, Marys Pond is in an Abies lasiocarpa habitat type containing Picea engelmann, Larix occidentalis, Pinus contorta and Pseudotsuga menziesii.

Tsuga heterophylla appears in the pollen record for the first time in this zone. The pollen is probably a result of long distance transport since only four grains were observed. Today, the nearest Tsuga heterophylla occurs at least 70 km to the northwest. Still, the timing of the pollen corresponds with results at Big Meadow in northwestern Washington (Mack *et al.*, 1978b), Hager Pond in northern Idaho (Mack *et al.*, 1978a; Mehringer, personal communication) and Smeads Bench Bog in northwestern Montana (Chatters and Leavell, 1994) where Tsuga heterophylla did not appear until after 2000 yr B.P.

Pines

Pinus dominates the entire pollen record comprising as much as 80% of the terrestrial pollen counted. Pine pollen declines noticeably several times and warrants some consideration (Figure 3). The first is at the bottom of the core in Zone I where the relative frequency of Pinus is only 50%. After a steady increase, pines declines again to 59% at 155 cm depth. This corresponds with a distinct increase in the relative abundance of Juniperus, Alnus and Artemisia, therefore it could simply reflect constraint in the percentage diagram. The dip to 51% at 120 cm depth directly follows an exceptional abundance of charcoal fragments at 125 cm depth. Presumably, the decline in Pinus is at least partially due to the preceding period of fires. The last place where the Pinus declines is at the very top of the core. This is also marked by an increase in NAP to AP (particularly Alnus) and charcoal to terrestrial pollen. This may again reflect the influence of fire on the vegetation.

A distinction between diploxylon (i.e. lodgepole pine and ponderosa pine) and haploxylon pine (i.e. whitebark pine) was made whenever possible. A percentage diagram of diploxylon to haploxylon pine clearly shows the dominance of diploxylon through out the pollen sequence (Figure 6). This may be a result of processing the pollen in the laboratory (resulting in breaking or tearing of grains) or a misidentification of pollen type. However, the six Pinus contorta macrofossil needles used for ^{14}C dates (Table 2) tend to corroborate the abundance of diploxylon pollen grains.

Possibly the dominance of diploxylon pines is a consequence of the particular elevation, climatic conditions, and ecological setting of Marys Pond. An increase in haploxylon pines over diploxylon pines was used at Lost Trail Pass Bog (Mehringer *et al.*, 1977a) and Sheep Mountain Bog (Mehringer, 1985) as an indication of shifting climatic conditions. At Marys Pond, an interpretation of climatic variations must be made using the other conifers present at the site.

Bog Development

The presence and abundance of aquatic pollen grains and plant cells, including members of the Cyperaceae family, are often indicators of fluctuating water levels. Menyanthes and Scheuchizeria have relatively large pollen grains and grow on lake margins, thus their presence in Zone III might suggest the edges of the pond were closer to the center where the core was taken. Scheuchizeria occurs once more at the beginning of Zone IV, but neither it nor Menyanthes were observed again after 60 cm depth. Perhaps water levels rose pushing the margins of the pond outward forcing the taxa on the waters edge away from the center. The Nuphar leaf hair base cells show a definite increase in abundance after 2000 yr B.P. (Zone IV) compared with earlier times. This may also be related to changing water levels and the proximity of the pond edge to the center.

Fire History

Examination of the charcoal to total terrestrial pollen ratio highlights two dramatic periods of increased charcoal in the core with a backdrop of low to moderate charcoal abundance throughout the remainder of the core (Figure 11). These two charcoal peaks (at 1.25 m and 1.05 m depth) are discussed in more detail below. The charcoal to total terrestrial ratios average around 0.35 suggesting numerous variable fires. This is the same scenario that occurred at Lost Trail Pass Bog where some charcoal was present in all the samples. Mehringer *et al.*, 1977a, interpreted this as evidence for "frequent small or low to medium intensity fires in the Bitterroot Mountains. Catastrophic fires in the Lost Trail Pass area are apparently the exception."

The presence of moderate amounts of charcoal throughout the sediment core is substantiated by the charcoal accumulation rates per centimeter squared per year (Figure 12). Aside from the two periods of large charcoal values at 1.25 m and 1.05 m depth, the graph illustrates that charcoal influx has remained relatively constant (and low) for the past 6800 years in the samples analyzed.

Some discussion has been given to additional interpretations of fire history based on size-classes of microscopic charcoal (MacDonald *et al.*, 1991). Tolonen (1986) argued a higher proportion of large charcoal fragments

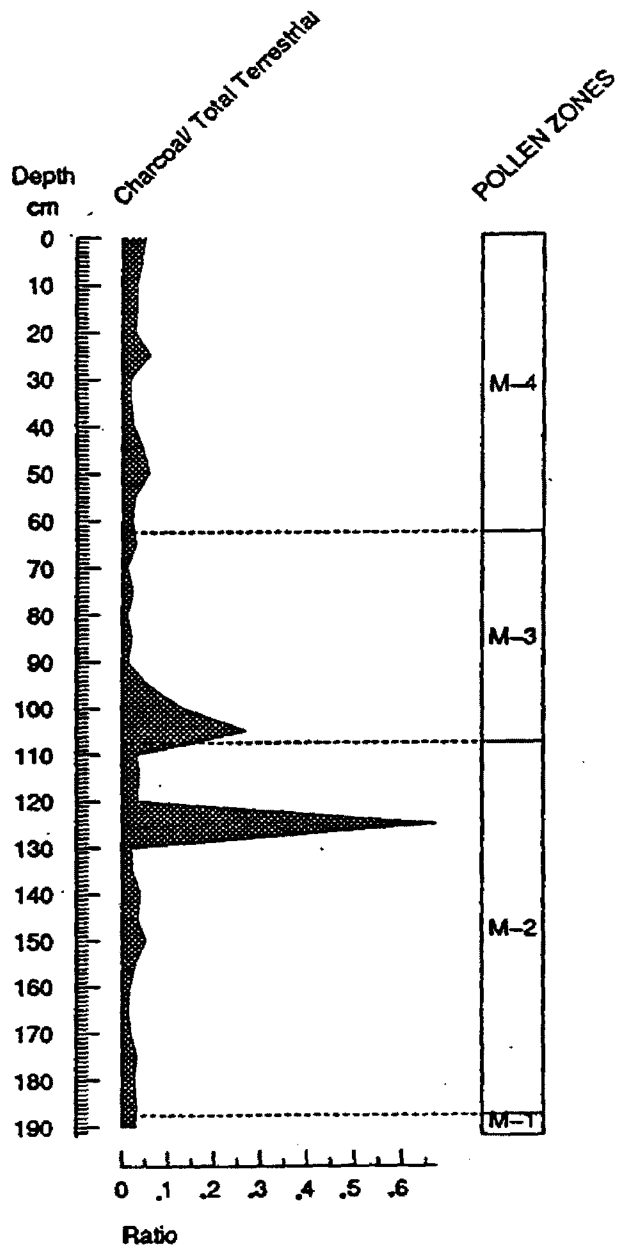

Figure 11. Ratio of total charcoal fragments to total terrestrial pollen grains.

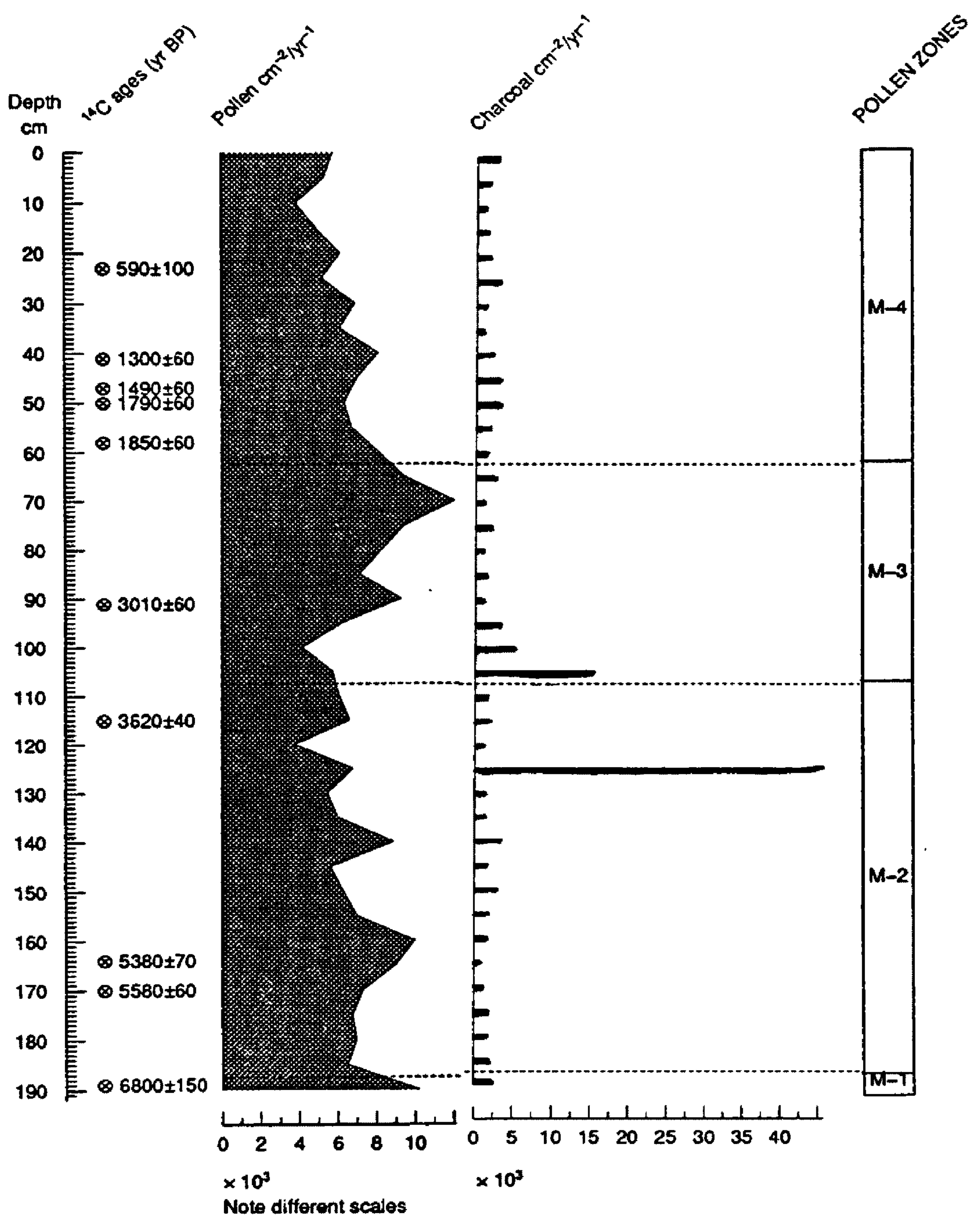

Figure 12. Pollen grains and charcoal fragments accumulation rates cm^{-2} year^{-1} at Marys Pond, Montana.

indicates periods when fires burned close to the basin they are deposition in. Clark (1988) studied the transport of charcoal particles and found that fragments greater than 50 μm diameter indicate local fires. It is also thought that finer ash particles indicate a more rigorous or distant fire (Patterson *et al.*, 1987).

The charcoal fragments at Marys Pond were separated by the following size classes: 25-50μm, 50-100μm and greater than 100μm. A diagram of these three size classes based on accumulation of grains per centimeter squared per year illustrates that majority of the microscopic charcoal fragments are within the 25-50μm category (Figure 13). The frequency of charcoal in the other two size classes are essentially identical to each other until the top 50 cm of the core. The past 2000 years shows an increase in the 50-100 μm size class over the $<$100μm charcoal fragments.

Three interpretations can be offered for the dominance of charcoal fragments in the smallest size. First, this could be a by-product of the laboratory processing procedure. It is conceivable that the charcoal fragments were broken down into small fragments from the amount of mixing necessary to process the samples. Second, it could be indicative of the proximity of fires to the pond. It is reasonable to conclude that smaller charcoal fragments will be transported greater distances. Lastly, the abundance of small charcoal particles might indicate more vigorous fires (Shaefer, 1974). Based on other studies from this region and the pollen composition of the entire core, this last interpretation seems most unlikely. It is more reasonable to suggest that fires occurred in frequent intervals at moderate intensities as a mosaic across the landscape. Consequently, the charcoal influx varies little except in the two periods described below.

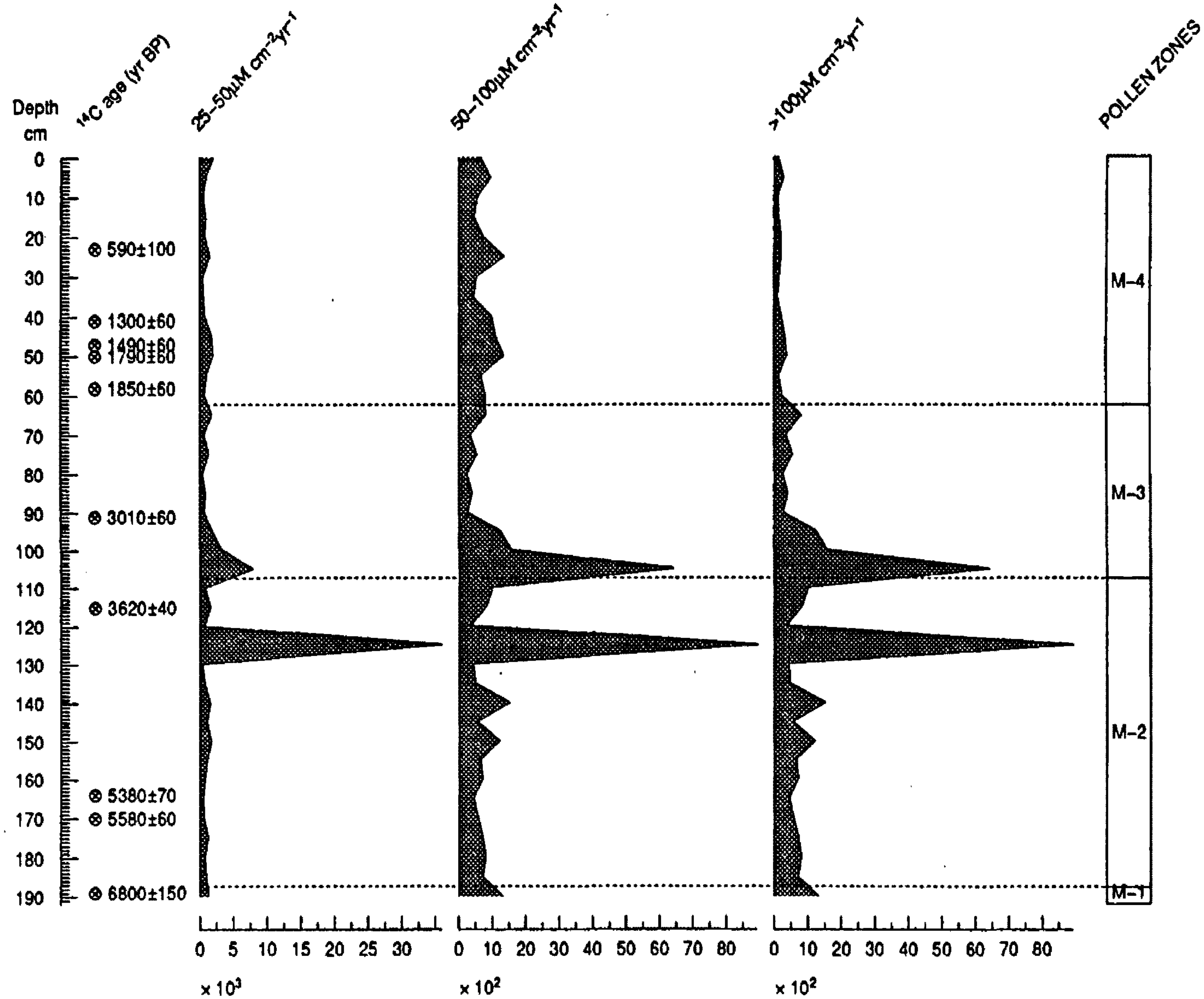

Figure 13. Charcoal accumulation rate of three size classes cm^{-2} year^{-1}.
(Note different scales between 25-50 μm and 50-100μm, >100μm.)

Charcoal Peaks at 3300 yr B.P. and 4000 yr B.P.

Two charcoal peaks stand out in the charcoal to total terrestrial pollen ratios and charcoal accumulation rates $cm^{-2} yr^{-1}$. These occur at 1.25 m (~ 4000 yr B.P.) and at 1.05 m depth (~ 3300 yr B.P.). Similar patterns occur with the charcoal to terrestrial pollen ratios, charcoal accumulation rates and pollen percentages at these two places in the sediment core.

The charcoal peak at 1.25 m is the larger of the two (Figure 11). Whereas from Mazama tephra up to this point the charcoal accumulation rate averages 2000 grains $cm^{-2} yr^{-1}$, this peak contains 45,804 grains $cm^{-2} yr^{-1}$; more than a twenty-two fold increase! Depending on variations in sedimentation rate, a dramatic increase in charcoal accumulation might be a by-product of more years being represented in fewer centimeters (Hemphill, 1983). However, the sediment deposition rate at Marys Pond remains relatively constant throughout the core (Figure 4). Therefore, it might be interpreted that this distinct episode of tremendous charcoal accumulation does represent a period of greater fire frequency or intensity relative to all other portions of the pollen core. The ratio of charcoal to terrestrial pollen further accentuates this point where the ratio jumps from 0.19 at 1.30 m depth to 6.73 at 1.25 m depth.

Several other things occur in the pollen record and organic content of the sediments around the same time as this increase in charcoal. Just after this peak in charcoal, the ratio of NAP to AP pollen reaches its highest value since Mazama tephra at 1.20 m depth. The relative frequency of Alnus increases and Ceanothus is present in the sample at 1.20 m depth (both taxa are frequently associated with fires). Additionally, the overall accumulation of pollen grains $cm^{-2} yr^{-1}$ declines from 6808 grains $cm^{-2} yr^{-1}$ before the charcoal influx, to 3748 grains $cm^{-2} yr^{-1}$ afterwards (Figure 12). Lastly, at 1.25 m depth, the percent of organic carbon in the sediments dips from 31.9% to an all time low of 19.5% (Figure 5).

The aquatics appear to be effected by the charcoal influx as evidenced by a significant peak in Botryoccus (Figure 3). This increase in the Botryoccus is interesting for it might parallel the findings of an experiment conducted at Hubbard Brook, New Hampshire. All the vegetation in a small forested watershed was cut down and all the regrowth the next spring was eliminated. Due to the removal of forest canopy cover, the light and water temperatures increased. As a result, the nitrate levels skyrocketed which led to a prolific growth of algae (Bormann and Likens, 1979). Could the increase in algae at Marys Pond be due to increase in nitrogen deposition after the reduction in forest canopy surrounding the pond because of catastrophic fires?

Many of these same patterns were observed in the charcoal peak at 1.05 m depth, but to a lesser degree. Charcoal grains per centimeter squared per year in this sample was 15,516 (about an eight fold increase from the sample just below at 1.10 m depth). The charcoal to terrestrial pollen ratio jumps from 0.317 to 2.698. The pollen accumulation rate responds to the increased charcoal as evidenced by a decrease from approximately 6000 grains $cm^{-2} yr^{-1}$ before the peak to around 4000 grains $cm^{-2} yr^{-1}$ afterwards. The Alnus and algae increase in relative frequency and Ceanothus is present in the sample. Once again, the percent organic content dips from 45.3% before the charcoal peak to 19.8% when the charcoal influx occurs.

One interpretation of the charcoal peaks is the concept of a double or triple burn. Barrett (1982) describes this as a reburn whereby there is a "recurrence of fire over an area at a time when many of the fuels burned by previous fire are available to burn a second time and when tree regeneration is in the seedling/sapling stages". Essentially, the initial burn creates the conditions for a second or third burn by leaving snags and down logs (Wellner, 1970). If an area did burn repeatedly one might expect a tremendous influx of charcoal washing into the pond sediments.

In order to place these charcoal peaks in time, it is interesting to note that the biggest one occurs in Zone II just before the transition between Zone II and Zone III. This is when it is inferred that the conifer composition changes from a Pinus and Pseudotsuga/Larix forest to Pinus with a more even mixture of Pseudotsuga/Larix, Abies and Picea. The change in forest types has been interpreted as a potential change in climatic conditions from warmer, less effective moisture to cool, moister condition. The second charcoal peak in Zone III is also near the transition between zones.

SUMMARY AND CONCLUSIONS

This study was initiated to elucidate the past vegetation communities and fire history of the area surrounding Marys Pond in the Bitterroot Mountains, Montana. A glimpse of how the plant assemblages have shifted through time can contribute to some general interpretations of the ecological conditions that may have been present at a particular time in the past. The microscopic charcoal provides one method for looking at disturbance and what impact it may or may not have had on the surrounding vegetation. A summary of the pollen and charcoal analysis at Marys Pond follows.

(1). The plant composition initially following Mazama ash is unique from all other portions of the core due to the importance of NAP to AP. This phenomena also occurs at Sheep Mountain Bog.

(2). Since Pinus dominates all other conifers at Marys Pond, the relative frequency of Picea, Abies and Pseudotsuga- Larix was used to illustrate shifts in plant assemblages. Based on these three taxa, three distinct periods are evident from the initial rise in NAP to the present. A general interpretation of moisture and temperature was extrapolated from these results.

(3). From 6200-3500 yr B.P., the Pseudotsuga-Larix pollen dominates over Picea and Abies. This suggests an apparent warming that has been observed at numerous other sites in the interior Pacific Northwest.

(4). A shift towards cooler temperatures and more effective moisture was suggested from 3500-2000 yr B.P. by the same general abundance of all three taxa. This climatic trend was observed at Smeads Bench Bog in the Cabinet Mountains and Lost Trail Pass Bog in the Bitterroot Mountains.

(5). By 2000 yr B.P. the forest communities seem to resemble the habitat presently surrounding Marys Pond. Abies and Pseudotsuga-Larix tend to dominate over the Picea.

(6). Compared to two catastrophic fire events, the remainder of the 6800 yr chronology suggests nearly continuous occurrence of moderate intensity fires in the area.

(7). Two peaks in charcoal fragments were recorded at ~ 3300 yr B.P. and ~ 4000 yr B.P. These have been interpreted as periods of increased fire activity based on microscopic charcoal, pollen accumulation, vegetation composition and organic content of the sediments.

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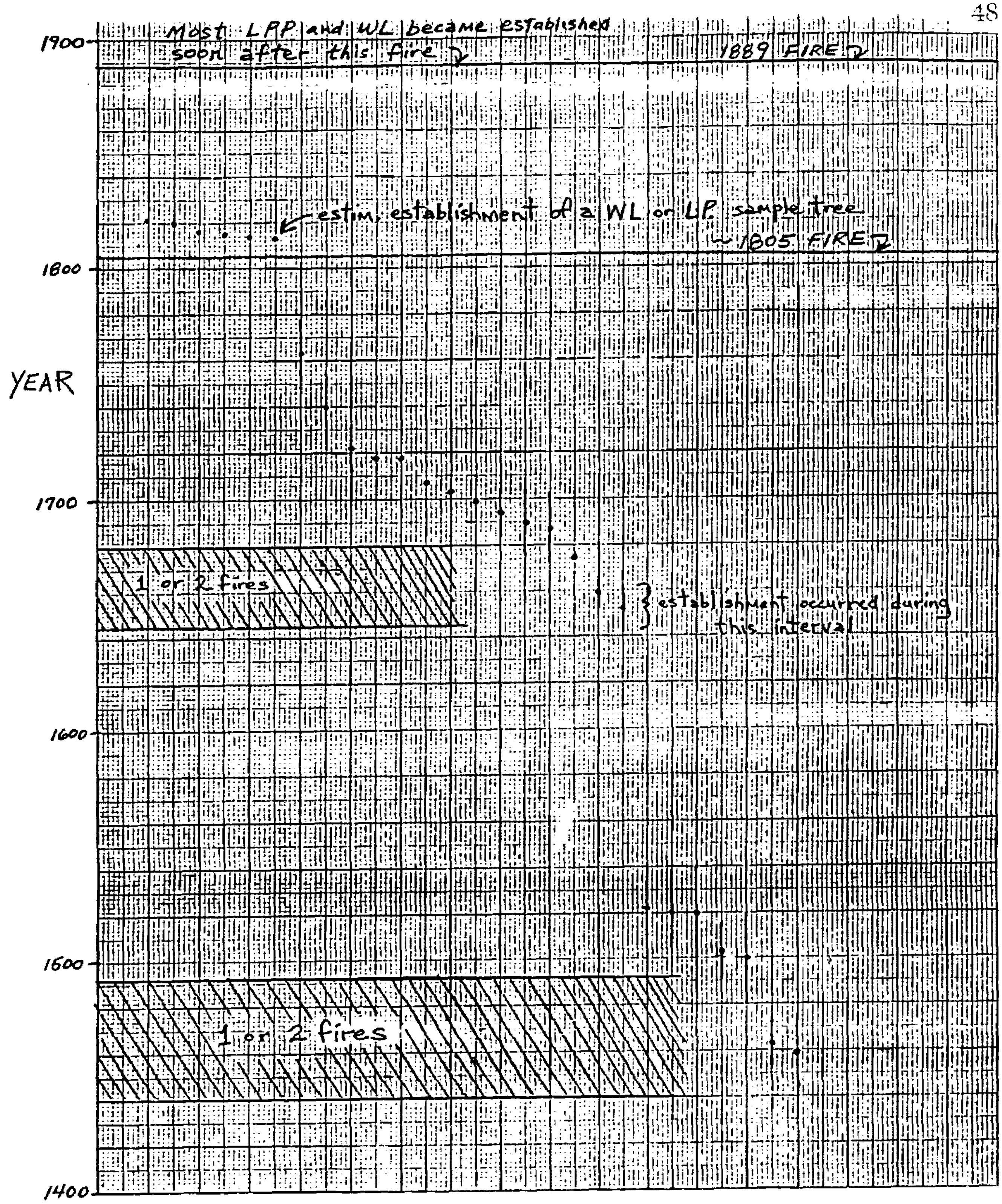

APPENDIX A: History of severe fires at Marys Pond, Lolo National Forest. The 1889 and 1805 fires were dated from fire scars. Earlier fires were interpreted from dates of establishment of shade-intolerant trees that survived subsequent fires. These veteran trees are Larix occidentalis except for a few Pinus contorta dating from the early 1800's.

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